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Macroscopic, petrographic and XRD analysis of Middle Neolithic *figulina* pottery from central Dalmatia

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ABSTRACT

This article focuses on macroscopic, petrographic and X-ray Diffraction (XRD) analyses of *figulina* pottery from Middle Neolithic (c. 5500–4900 cal BC) villages on the Dalmatian coast of Croatia. Samples were collected from four sites: Smilčić (Zadar), Krivače and Danilo Bitinj (Šibenik) and Pokrovnik (Drniš) to characterize the degree of variation in *figulina* production between sites and assess if *figulina* was produced locally or at a single locale in the region. *Figulina* is of particular interest because it represents a departure from other Neolithic ceramic technologies in pastes, firing, and decoration. This ware is found in small numbers at Middle Neolithic villages, but has parallels in the northern and western Adriatic. Our analyses suggest that this ware was produced within villages with little exchange between sites. Similarities to other regions (Istria, Italy) may indicate a special function or role of this pottery style within Middle Neolithic societies.

1. Introduction

The central Dalmatian coast of Croatia is defined by a karst limestone landscape with relatively small, elongated valleys divided by low hills. Beginning ca. 6000 cal BC, early farmers produced Impressed Ware pottery throughout the eastern Adriatic. The ceramic repertoire expanded during the Middle Neolithic (ca. 5500–4900 cal BC), known as the Danilo culture, to include various innovations in ceramic technology (Fig. 1). Paralleling developments elsewhere in the Adriatic, ceramic styles became regionalized and diversified, and included a mix of coarse and fine wares, as well as a greater array of vessel forms including plates and open bowls. In the case of central Dalmatia, decoration styles changed dramatically from impressed motifs to incised and carved curvilinear designs on typical Danilo wares. In addition, two new types of pottery were introduced: anthropomorphic or zoomorphic footed vessels known as rhyta (Rak, 2011), and high-fired, painted buff wares known as *figulina* (Batović, 1979: 544–548; Chapman, 1988; Korošec, 1958: 40–53, 1964: 33–40; Spataro, 2002) (Fig. 2).

Unlike everyday (smudged and non-smudged) Danilo pottery, *figulina* was widely distributed in Middle Neolithic assemblages throughout the Eastern and Western Adriatic (Chapman, 1988; Malone, 2003; Robb, 2007; Spataro, 2002, 2009). Few chemical or petrographic characterizations of *figulina* are available for Dalmatia, and Spataro (2002) is the only published dataset. In her comparison of Neolithic ceramic technology throughout the Adriatic, she suggests that *figulina* production in Dalmatia was independent of production elsewhere in the Adriatic. This paper complements Spataro's (2002) pioneering work by focusing on larger sample sizes from four open-air sites within a defined region, the central Dalmatian coast, to assess the degree of variation in *figulina* production between sites. By analyzing the petrography and mineral composition, we examine to what extent *figulina* was produced locally (i.e., within 4 km of the village) or if there is evidence for regional production centers on the Dalmatian coast.

1.1. Dalmatian Middle Neolithic

The earliest farming populations in central Dalmatia are recorded at ca. 6000 cal BC and are characterized by the establishment of villages, reliance on agropastoral subsistence, and a distinctive pottery known as Impressed Ware. By the Middle Neolithic (ca. 5500–4900 cal BC), relatively little changed in terms of subsistence

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Fig. 1. Location of sites mentioned in the paper: 1) Smilčić; 2) Krivače; 3) Pokrovnik; 4) Danilo Bitinj; 5) Ripoli; dashed line limits the area of the distribution of the Middle Neolithic Danilo culture and its local variations.

or settlement strategies, however clear shifts are visible in ceramic typologies and technologies and there is increased evidence for long-distance exchange with the incorporation of obsidian into stone tool technologies (for recent radiocarbon dates on the Neolithic chronology of the Eastern Adriatic see Forenbaher et al., 2013; Forenbaher and Kaiser, 2008:23–27; Komšo, 2006; Legge and Moore, 2011; Marijanović, 2009:107–141; McClure et al., 2014; Miracle and Forenbaher, 2006:497–517; Moore et al.,

Fig. 2. Suite of Danilo wares from Danilo Bitinj. Photo courtesy of the Šibenik City Museum.

Fig. 3. Selection of *figulina* from Danilo Bitinj. Photo courtesy of the Šibenik City Museum.

2007a, 2007b; Podrug, 2010). The suite of Middle Neolithic pottery, consisting of fine and coarse wares with a variety of incised or painted decorations in a range of open and closed shapes, defines what is known as the Danilo culture (Fig. 2) and is a clear departure from earlier pottery styles and production in the region. This Danilo culture complex extends along most of the Eastern Adriatic coast and its hinterland (from the peninsula of Istria to the Montenegro coast) in some variation, but its typical version is best documented in the fertile valleys of Dalmatia (Batović, 1979: 524–633).

Danilo wares are characterized by new elaborations in ceramic expression. Pottery types occur in three main categories: 1) everyday ware (coarse and fine); 2) cult or ritual vessels such as rhyta; and 3) *figulina* fine wares (Batović, 1979: 540–551, 559–560; Biagi, 2003; Korošec, 1958: 40–93, 1964: 25–49; Fig. 2). Fine everyday ware can be plain, decorated with various incised designs (such as spirals) or smudged and burnished. Rhyta are typically four-legged zoomorphic and/or anthropomorphic handled vessels (Rak, 2011). *Figulina* can be further divided into two types, which include bi-chrome painted wares and a red or buff monochrome ware (Fig. 3; Batović, 1979: 544–548; Chapman, 1988; Korošec, 1958: 40–53, 1964: 33–40).

Ceramic diversification is a common feature throughout the Adriatic and Mediterranean during the Middle Neolithic (e.g., Chapman, 1988; McClure, 2011). What is striking about the Danilo Neolithic, however, is that the only archaeologically visible changes in Neolithic lifeways are in pottery style and manufacture. Subsistence strategies, settlement locations, and stone tool technologies remain largely unchanged between the Impressed Ware and Danilo Neolithic. It is only the clear technological and stylistic shifts in pottery that indicate some type of social or cultural change during this period. Among these new shapes, forms, and techniques of pottery manufacture, figulina pottery stands out as a clearly distinctive ware with little apparent connection to earlier Impressed Wares or to contemporary everyday wares. For this reason, characterizing the mode of production of *figulina* wares is of particular interest.

1.2. Figulina Pottery

Figulina pottery first appeared on the Dalmatian coast of Croatia during the Middle Neolithic (Danilo; ca. 5500–4900 cal BC) and persisted in some parts of the Adriatic for the following 500 years (Forenbaher et al., 2013; Spataro, 2002). The term *figulina* is commonly used to describe a Neolithic fine ware, characterized by Malone (1985) as a buff "untempered, polished, evenly-fired material." In Dalmatia *figulina* appears most frequently as reddish-yellow/orange, pink, and cream vessels that were often slipped. The designs consisted mainly of linear and geometric motifs painted with white, brown, black, and/or red pigments (Fig. 3).

In Dalmatia *figulina* is found in a relatively small proportion of pottery from Neolithic sites (Batović, 1979: 554): ca. 4% at Danilo Bitinj and ca. 1.5% at Pokrovnik.[1] In comparison to other Danilo-phase pottery, it is very finely textured, fired in an oxidizing atmosphere, has few to no inclusions, and appears in a suite of forms including open and closed vessels.

Danilo *figulina* ware was first analyzed in the 1950's after the initial excavation of the eponymous site of Danilo Bitinj. Due to its striking difference to the predominant Danilo pottery (coarse and fine wares, often reduced fired and/or smudged, incised or carved decorations), *figulina* ware was thought to have been a special pottery category with close resemblance to contempory Ripoli fine painted ware on the Middle Adriatic coast of Italy. The excavator of Danilo Bitinj, J. Korošec, noted that despite the overall resemblance of the *figulina* ware from Danilo and Ripoli sites, the shapes and painted ornamental patterns have substantial differences. This led Korošec (1958) to conclude that Danilo *figulina* was not an import ware from the Ripoli culture or vice versa. Rather, Korošec argued that the relatively close resemblance of the two pottery styles pointed to intensive social connections and cultural influences between the two Adriatic coasts during the Middle Neolithic. This view was further supported by the correlation of the results of the first chemical analyses of *figulina* pottery sherds from the site of Danilo Bitinj with *figulina* sherds from three Ripoli sites in Italy (Korošec, 1958: 107–116). Despite the lack of a larger geochemical study, Korošec later concluded that *figulina* pottery in Danilo phase must have been produced locally on the village scale (Korošec, 1964: 56–59, 66). In the 1970s Batović (1979: 563–570) agreed that *figulina* vessels were not imported from Italy and were instead

[1] Preliminary data on the relative percentage for *figulina* pottery is only available for Danilo Bitinj (excavation campaigns 2004 and 2005) and Pokrovnik (excavation campaign 2006) (Moore et al., 2007a, 2007b). For Smilčić and Krivače no such data are available.

produced locally, probably resulting from interactions with the Eastern Mediterranean, especially the Italian coast where painted pottery ware developed earlier than in Dalmatia.

Recent investigations of *figulina* indicate that this ware from both Italy and Dalmatia was manufactured using a specific type of raw material rich in calcium, iron, potash, and manganese (Spataro, 2009). Vitrification of *figulina* provides evidence for firing temperatures upward of 850 °C (Spataro, 2002). These temperatures can be reached in an open pit firing and it is possible that *figulina* produced in Dalmatia was produced without a kiln (Rice, 1987). On the other hand, Korošec (1958: 40–41; 1964: 33) and Batović (1979:544) argued that *figulina* had to be fired in a kiln due to the evenness of oxidation and resulting color. At this time there is no direct evidence for kilns in Middle Neolithic Dalmatia.

1.3. *Figulina and Middle Neolithic pottery production*

If the majority of Danilo pottery (coarse and fine wares) typifies the texture and composition of local clays, then production of *figulina* vessels from these clay sources required an increased level of raw material processing (Jones, 2008). A *chaine operatoire* approach to ceramic technology (Table 1; see McClure, 2011) would characterize clay processing for *figulina* in the following manner. First, local clays required levigation, a process of extended soaking of clay in water, to separate large minerals from the clay body (Rice, 1987). To increase the plasticity of the clay and its thermal properties for firing, temper would need to be finely ground and sieved. The clay matrix would have been formed into the desired shape and dried. A slip would have been applied and allowed to dry, followed by a painted decoration, and then dried again prior to firing in an open air pit or dedicated kiln to temperatures up to 900 °C in an oxidizing environment. In contrast, common Danilo wares would have much lower time and effort costs associated with its production.

Mineralogical study of *figulina* can be employed to identify a "production group" or "community geologic signature" (Costin, 1991). Pottery made in a specific resource area (assuming that potters collect resources from a 3–4 km radius from settlement) will have a community geologic signature or "community resource area" (Arnold, 2000). Interaction of potters within a specific community often translates into similarities in style, material and processing choice (Arnold, 2000; Lemonnier, 1980; McClure, 2007, 2011). "Community geologic signatures" act to differentiate communities outside the resource area (Arnold, 2000). Subtle variation in paste compositions provide a window into unintentional standardization resulting from unconscious patterning that acts as a signature of a potter or workshop. Greater variability in paste compositions between sites implies a lower degree of specialization and a greater number of production locales.

2. Materials and methods

Community geologic signatures are identified based on a study of mineral compositions of *figulina* pottery using macro-visual, petrographic and X-Ray Diffraction (XRD) techniques (Table 1; see also Inline Supplementary Table S1). A representative sample of *figulina* pottery ($n = 15$–25) was collected from each of the four sites and includes the range of paste colors in the assemblages. The majority of the sample consists of reddish-yellow/orange samples, as these were the most common color group found at each site. Samples were first analyzed macro-visually following Rye (1981) using a 5× hand lens in order to document firing atmosphere, paste texture, and inclusions (relative abundance and size). These data including inclusion size, roundness, sorting, and frequency are used to define *figulina* pastes (Table 2).

Table 1
Summary of samples for macro-visual, petrographic and XRD analyses (for details on sample provenience and decoration see Inline Supplementary Table S1).

Site	Total number of samples	Color			Petrographic analysis	XRD analysis
		Pink	Orange	Cream		
Pokrovnik	*21*	3	17	1	19	18
Danilo Bitinj	*23*	6	13	4	16	19
Krivače	*24*	4	13	7	13	15
Smilčić	*15*	2	11	2	13	15
Total	**83**	**15**	**54**	**14**	**61**	**67**

Inline Supplementary Table S1 can be found online at http://dx.doi.org/10.1016/j.jas.2014.07.007.

The sites of Danilo Bitinj and Pokrovnik were targeted for two reasons: 1) the proximity (10 km) of the two sites creates a good context for testing hypotheses of local versus regional production; and 2) they were both recently excavated, allowing a selection of contemporaneous samples, dating to ca. 5300–5100 cal BC (Legge and Moore, 2011; Moore et al., 2007a, 2007b). In order to obtain a more complete picture of *figulina* production in Dalmatia, samples were also collected from Smilčić and Krivače. These samples came from older excavations at Smilčić (conducted in 1956–59 and 1962; Batović, 1979) and older surface collections and smaller test excavation at Krivače (conducted in 1963; Korošec and Korošec, 1974).[2]

Petrographic analysis of thin sections identified mineral inclusions and allowed us to construct paste recipes. Thin sections were prepared at the University of Oregon's (UO) Center for Advanced Material Characterization (CAMCOR) and analyzed using a petrological polarizing light microscope in the UO Department of Anthropology. Minerals were identified in thin section and macroscopic analysis recorded inclusion size (.2–2 mm), frequency (<5%, 5–10%, 20–30%), and sorting (poor, well) (Barraclough, 1992; Fargher, 2007; Orton et al., 1993; Matthew et al., 1991; Rice, 1987; Rye, 1981). These mineral and textural features of the pastes were coded in order to be analyzed using SAS/STAT Software (see Inline Supplementary Table S2). X-ray Diffraction was performed on a Bruker AXS D8 Discover XRD System at the UO CAMCOR facility. To ensure that only the ceramic paste was examined, the exterior surfaces of the ceramic samples were scraped clean of dirt and slip. The samples were then ground with an agate mortar and pestle in preparation for analysis. Spectra recorded diffraction intensity from 5 to 90°2Θ (theta). The spectra were analyzed manually using DiffractEVA software.

Inline Supplementary Table S2 can be found online at http://dx.doi.org/10.1016/j.jas.2014.07.007.

3. Results: macro-visual and petrographic analyses

The results of the analyses are presented by site and analysis type. Detailed data descriptions are also available in the Inline Supplements (see also Teoh, 2011). Table 2 summarizes the identified fabric types.

Twenty-one samples were collected from the Middle Neolithic levels at Pokrovnik Trench D and date to approximately 5300–5100 cal. BC (McClure et al., 2014). Macro-visual analysis of all Pokrovnik samples indicate that in all color categories *figulina* samples have very fine–fine inclusions with a frequency between 1% and 5% (Teoh, 2011). Only one sample of pink *figulina* shows coarse inclusions. Nineteen samples were analyzed in thin section

[2] Archaeological material from the sites of Danilo Bitinj and Krivače are housed at the Šibenik City Museum, from Pokrovnik at the Drniš City Museum, and from Smilčić at the Archaeological Museum of Zadar.

Table 2
Figulina fabric types by color and site.

Site	Figulina type	Fabric group	Fabric description
Pokrovnik	Orange	PF1 ($n = 7$)	Calcareous clay with low frequencies of well-sorted fine sub angular quartz and tempered with poorly sorted irregularly shaped calcite (typical size ranging between 0.2 mm–0.8 mm).
		PF2 ($n = 2$)	Calcareous clay with low to moderate frequencies of fine well-sorted sub-angular quartz and calcite and were tempered with large irregularly shaped calcite.
		PF3 ($n = 7$)	Calcareous clay free of irregularly shaped calcite inclusions with low frequencies of fine sub-angular quartz.
	Pink	PF4 ($n = 2$)	Calcareous clay with high frequencies of small well-sorted sub-angular quartz and well-sorted fine calcite.
	Cream	PF5 ($n = 1$)	Calcareous clay with low frequencies of well-sorted fine-grained rounded calcite and sub-angular quartz.
Danilo Bitinj	Orange	DF1 ($n = 4$)	Micaceous clay with rare opaque inclusions and low to high frequencies of well-sorted fine quartz. Sample DA10 is the only sample that appears to have been tempered with calcite.
		DF2 ($n = 2$)	Calcareous clay with low frequencies of fine well-sorted rounded quartz inclusions.
		DF3 ($n = 2$)	Coarse-grained micaceous clay with an abundance of well-sorted micas and sub-angular quartz mineral inclusions and no opaque inclusions.
	Pink	DF4 ($n = 4$)	Micaceous clay matrix with low frequencies of well-sorted fine-grained sub-angular quartz and mica inclusions. Opaque inclusions appear in only one of the four samples.
	Cream	DF5 ($n = 1$)	Calcareous clay with low frequencies of fine rounded calcite and fine-grained rounded quartz and mica inclusions. Pores edged with calcite would suggest the previous presence of larger calcite inclusions, potentially used as tempers.
		DF6 ($n = 3$)	Micaceous clay with high frequencies of fine-grained well-sorted micas and low frequencies of well-sorted rounded quartz. Large rounded calcite can be found in sample DA6b suggesting calcite tempering.
Krivače	Orange	KF1 ($n = 1$)	Calcareous clay with low frequencies of fine well-sorted sub-angular quartz inclusions.
		KF2 ($n = 3$)	Calcareous clay with low frequencies of fine sub-angular quartz, mica, and opaque inclusions.
		KF3 ($n = 3$)	Micaceous clay with well-sorted moderate frequencies of fine sub-angular quartz, high frequencies of fine angular mica, and low frequencies of opaque inclusions.
		KF4 ($n = 2$)	Coarse-grained micaceous clay with moderate to high frequencies of poorly sorted fine to coarse sub-angular quartz and mica inclusions.
	Pink	KF5 ($n = 1$)	Calcareous clay with low frequencies of fine well-sorted sub-angular quartz and opaque inclusions.
		KF6 ($n = 1$)	Coarse-grained micaceous clay with an occasional opaque, and an abundance of well-sorted fine sub-angular quartz and poorly sorted fine and medium angular mica.
	Cream	KF7 ($n = 2$)	Calcareous clay with low frequencies of fine well-sorted quartz and opaque inclusions.
Smilčić	Orange	SF1 ($n = 1$)	Calcareous clay with low frequencies of fine sub-angular quartz.
		SF2 ($n = 2$)	Calcareous clay with a rare opaque and low frequencies of well-sorted fine-grained rounded calcite and sub-angular quartz, and tempered with rounded calcite.
		SF3 ($n = 1$)	Calcareous clay with low frequencies of fine well-sorted round calcite, sub-angular quartz, mica, and rare opaque inclusions.
		SF4 ($n = 3$)	Coarse-grained calcareous clay with rare opaque, and high frequencies of poorly sorted calcite including sparry calcite and dolomite ranging in size from 0.1 mm to 1 mm, and tempered with crushed calcite. Fine well-sorted sub-angular quartz and mica appears at low frequencies.
		SF5 ($n = 1$)	Micaceous clay matrix with rare opaque and low frequencies of well-sorted fine calcite, quartz, and mica.
		SF6 ($n = 2$)	Coarse-grained micaceous clay matrix with rare opaque, low frequencies of fine sub-angular well-sorted quartz, and high frequencies of poorly sorted angular mica (0.1 mm–.5 mm).
	Pink	SF7 ($n = 2$)	Calcareous clay with rare opaque, and low frequencies of fine well-sorted rounded calcite and quartz.
	Cream	SF8 ($n = 1$)	Calcareous clay with rare opaque and low frequencies of well-sorted sub-angular quartz.

(16 orange, 2 pink, and 1 cream). Despite all of the fabric groups identified at Pokrovnik being characterized by very fine paste with irregularly shaped calcite and quartz inclusions, five distinct groups could be determined based on the relative proportions, types, and sizes of the inclusions (Table 2).

Twenty-three samples were analyzed macrovisually from Danilo Bitinj and date to approximately 5300–5100 cal BC (McClure et al., 2014). Macro-visual analysis illustrates that at Danilo Bitinj in all color categories *figulina* samples have very fine–fine inclusions with a frequency between 1% and 5% (Teoh, 2011). Only one cream *figulina* sample had coarse inclusions, but it was present at a very low frequency <5%. Three distinct fabric groups were identified in thin section ($n = 16$) for the orange *figulina*. Fabric DF1 is most abundant and is characterized by fine-grained homogenous micaceous clay with low to frequent fine quartz inclusions. Danilo Bitinj pottery tends toward a lower porosity than that found at Pokrovnik.

The site of Krivače provided 24 samples for macro-visual and 13 samples for thin section analysis. Four fabric groups were identified for orange *figulina* pottery, two among the pink, and one group of cream *figulina*. Although the precise context of these samples is unknown, recent research at Krivače has resulted in a suite of radiocarbon dates spanning the same Middle Neolithic interval as for Pokrovnik and Danilo Bitinj (5300–5100 cal BC; McClure et al., 2014). *Figulina* from Krivače is largely untempered, but a few samples have evidence of possible calcite temper. Macro-visual analysis illustrates that across all color categories the majority of samples from Krivače have very fine-to-fine inclusions of a frequency ranging from 1% to 5% (Teoh, 2011). Only 9% of the reddish-yellow *figulina* had <5% of coarse inclusions. Two samples of the pink *figulina* have a range of fine to coarse inclusions.

Finally, Smilčić had the greatest variability in *figulina* fabric types. The macro-visual analysis illustrates that 70% of orange *figulina* samples have very fine–fine inclusions with frequencies between 0 and 5%. The remaining 30% have a range of inclusions sizes from very fine to coarse at a frequency of 10–15% (Teoh, 2011). Fourteen samples of *figulina* pottery were analyzed in thin section: 10 orange, 2 pink, and 1 cream sample. Six *figulina* fabric groups were identified at Smilčić among the orange samples, one fabric group for the pink, and one for the cream. The coarse-grained fabrics are unique to Smilčić and do not appear in any of the other sites. The two fine-grained fabrics resemble those found at Danilo Bitinj and Pokrovnik.

Figulina is generally known as a very fine, inclusion free paste, but some variation was noted in our analysis. A distinguishing characteristic of identified fabrics was the size of inclusions visible macroscopically and in thin section. Fig. 4 illustrates the relative percentage of inclusion size and frequency (captured as fine vs. coarse) among samples from each site and clear differences are visible between sites. In particular, the Pokrovnik samples were all

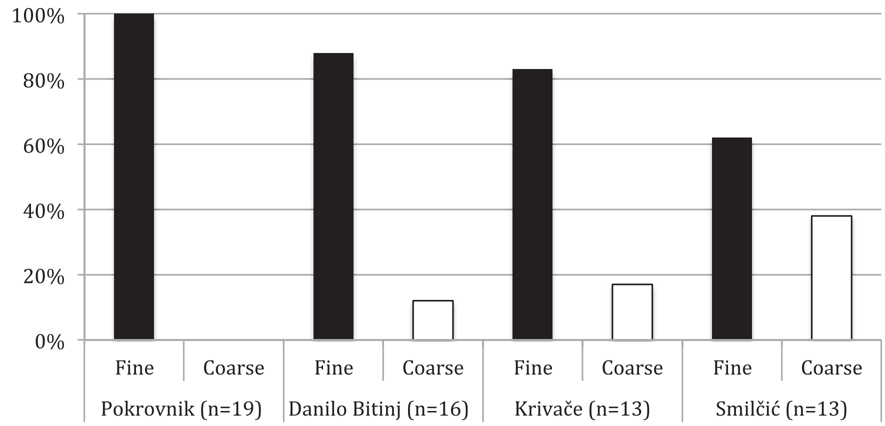

Fig. 4. Percentage of fine and coarse *figulina* fabrics from Pokrovnik, Danilo Bitinj, Krivače, and Smilčić.

fine, whereas other sites had at least some portion of coarse *figulina*. This may be due to sampling issues, however initial sample selection did not take macrovisual characteristics other than color into account. Instead, we suggest that this variation may be indicative of spatially independent production. Since potters levigated clay to create extremely fine raw material for *figulina* production, one would expect them to prepare a single large batch of clay rather than separate batches for individual vessels (Rice, 1987; Rye, 1981). Adding tempering agents to the matrix and forming and firing would likely have occurred during this time. In the case of Smilčić, potters appeared to be less concerned with the processing of *figulina*, 37% of the total samples were coarse grained. The variation in *figulina* fabrics in general and the high degree of variability in *figulina* from Smilčić suggests independent production of *figulina* from other sites.

To test this idea further, principal components analysis (PCA) was used to identify patterns in the petrographic and fabric data. As a multivariate statistical tool, PCA helps determine covariance between independent variables, with the ultimate goal of highlighting strong correlations underlying the original dataset. The statistical program SAS was employed to analyze the data. Variables identified in the petrographic and macro-visual analysis (see Table 1; $n = 61$) were assigned a value for PCA (Inline Supplementary Table S2). Fig. 5 expresses the PCA as a data plot with correlation coefficient of $r = .5$, indicating a strong relationship between the variables. Principal component 1 accounts for 36% of the total variation and principal component 2 accounts for 19%. PCA of petrographic datasets clustered most of Danilo Bitinj and Pokrovnik into two separate and distinct groupings, labeled G1 and G2 (Fig. 5).

In contrast, the remaining three groups (G3, G4, and G5) describe texture differences in *figulina* and are not based on specific sites: G3 describes samples with a fine-grained calcareous clay with low frequencies of fine quartz; G4 describes fine, densely packed, coarse-grained micaceous clay with an abundance of well-sorted micas and sub-angular quartz mineral inclusions; and G5 describes coarse-grained calcareous clay tempered with crushed calcite (Fig. 5; Inline Supplementary Table S2). Pokrovnik was the most standardized and uniform in paste composition, three fabric groups describe all the variation in the orange samples. All of the samples from Pokrovnik were fine-grained calcareous fabrics with high frequencies of calcite and no evidence of mica. The consistency

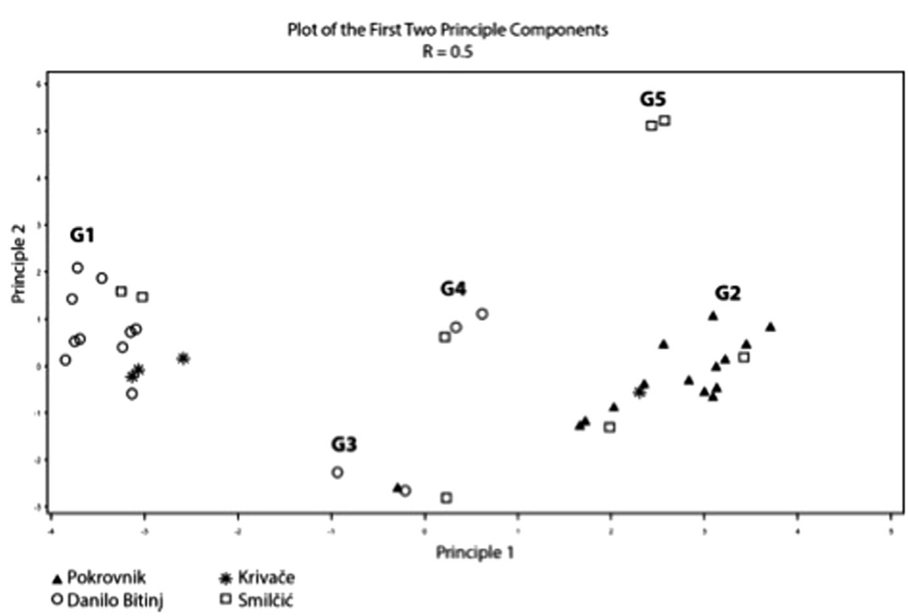

Fig. 5. Principal Component Analysis (PCA) of petrographic results of all *figulina* samples showing sites grouped into 5 distinct clusters.

of paste compositions from Danilo Bitinj and Pokrovnik combined with PCA analysis provides strong evidence for Pokrovnik and Danilo Bitinj as two separate locales of production. However, the other three groupings indicate that other behavioral processes, such introduction of non-local vessels or use of different clay sources, may have also been part of the story.

3.1. X-Ray Diffraction (XRD)

In order to characterize the clays and pastes used more effectively, *figulina* was analyzed using X-Ray Diffraction (XRD). Recent investigations of *figulina* using Scanning Electron Microscope-Energy Dispersive Spectrometry (SEM-EDS) illustrate that *figulina* from Italy and Dalmatia was manufactured using a specific type of raw material rich in calcium, iron, potash, and manganese (Spataro, 2009). The reasons for this preferential selection of clay are currently unclear. Calcium rich clays are not ideal for cooking because calcium oxide tends to fragment at high temperatures (Rice, 1987; Rye, 1981). This is consistent with the lack of fire clouding or other evidence of cooking on *figulina* wares, suggesting they were used for storage or serving. The choice of these raw materials may instead relate to color. Calcium oxide contributes to a whitish color and iron to a reddish color (Spataro, 2009). Vitrification of *figulina* observed by SEM-EDS provides evidence for firing temperatures upward of 850 °C (Spataro, 2002). Calcite decomposition begins between 600 °C and 900 °C and causes the release of carbon dioxide (CO_2) and the formation of lime (CaO) (Rice, 1987). When this reaction occurs in calcareous or illite clays, the free lime reacts with the clay to form diopside and wollastonite (Reedy, 2008).

XRD analysis of *figulina* suggests potters purposefully selected a similar type of clay containing muscovite, hematite, orthoclase (feldspar), quartz, and calcite. A PCA of the XRD dataset (identified minerals per sample) grouped most *figulina* samples into one cluster suggesting a similar mineral composition of all *figulina* pottery (Fig. 6; $n = 67$). Principal component 1 explains 25% of variation, while principal component 2 explains 22% of the total variation of *figulina* pottery.

Daub samples from Pokrovnik and Danilo Bitinj were also analyzed with XRD and compared with the *figulina* from those two sites (Fig. 7; $n = 37$). PCA analysis grouped daub samples closer to the *figulina* samples from their respective sites. Principal component 1 explains 22% of variation, while principal component 2 explains 23% of the total variation. Daub samples from Danilo Bitinj have a mineral composition that includes muscovite, calcite, quartz, orthoclase, and hematite, and match the *figulina* samples (Teoh, 2011). In contrast, daub samples from Pokrovnik only have calcite and quartz mineral phases, suggesting that clay from Pokrovnik tends to be more calcareous. This is interesting when considering the subsoils of Pokrovnik showed no calcite present, suggesting that clays used to build homes and produce pottery at Pokrovnik were collected from an off-site clay source (Fadem, 2009).

In addition, XRD analysis was used to determine firing conditions. Firing temperatures can be estimated based on the presence and absence of mineral phases. Calcareous clays go through a series of mineral transformations at different temperatures. In calcite rich clays the earliest changes begin with the transformation of goethite into hematite at 300 °C (Trindade et al., 2009). At 700 °C $CaCO_3$ decomposes yielding CaO (lime) and the release of CO_2 (Trindade et al., 2009). Calcite and illite remains in the clay body up to a temperature of 900 °C (Trindade et al., 2009). At 900 °C new crystalline phases nucleate yielding minerals such as wollastonite and gehlenite (Trindade et al., 2009). Although dolomite was not identified in thin section or in mineral phase, the presence of the diopside mineral phase is an indicator that dolomite minerals were

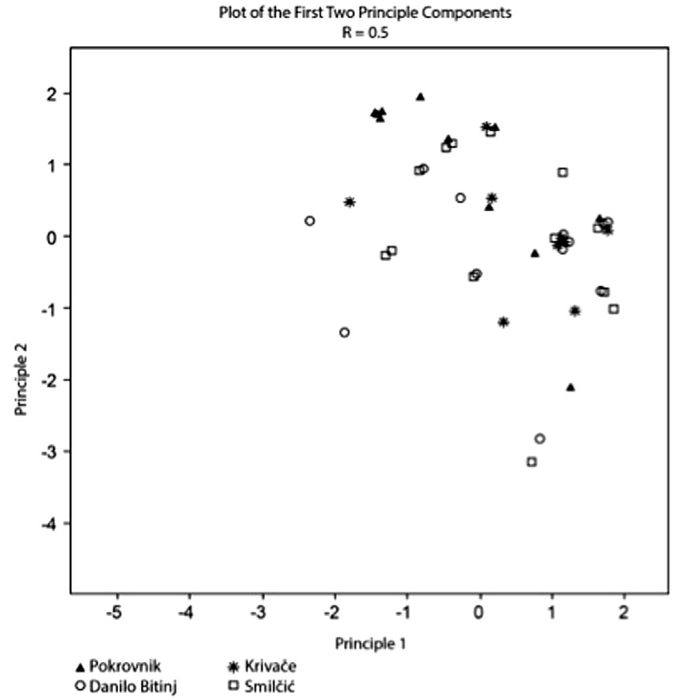

Fig. 6. Principal Components Analysis (PCA) of XRD results of *figulina* samples from the sites of Danilo Bitinj, Pokrovnik, Smilčić, and Krivače.

present in the clay body prior to firing. At temperatures between 800 and 900 °C dolomite decomposes to form diopside. Choosing calcareous clays enables potters to create pottery using less energy.

Some variability in firing temperatures was detected between sites (Fig. 8). XRD analyses of Pokrovnik samples show a significantly lower frequency of diopside than at other sites. This implies that *figulina* from Pokrovnik is dolomite-rich and calcite-poor. Of

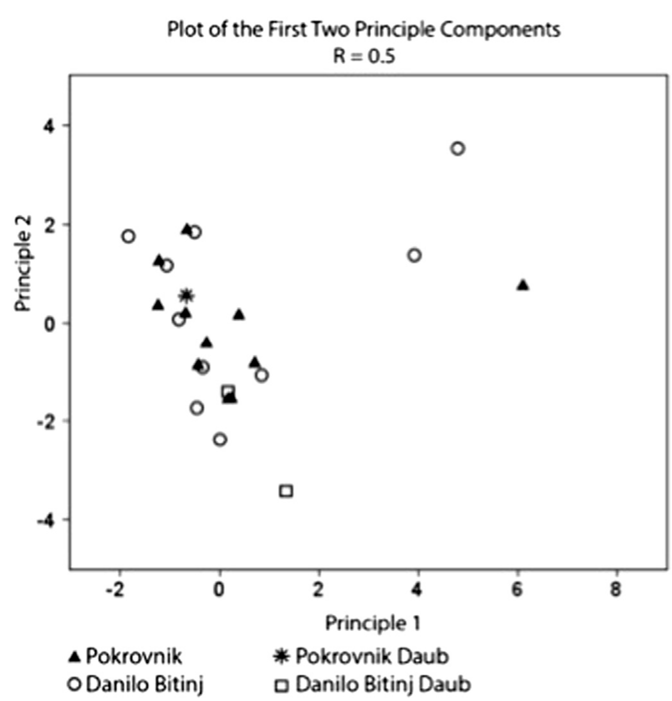

Fig. 7. Principal Component Analysis (PCA) of XRD dataset of *figulina* samples compared to daub samples from Danilo and Pokrovnik.

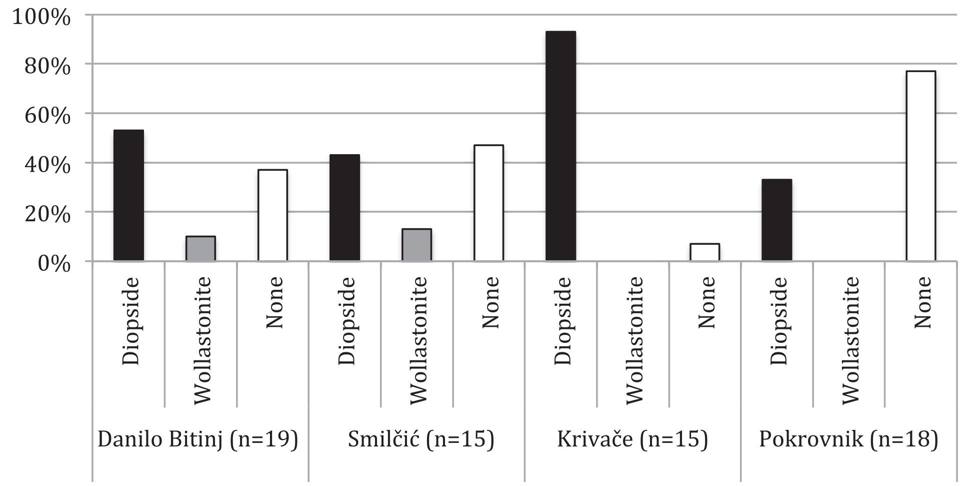

Fig. 8. Summary of high fire mineral phases identified in *figulina* using XRD.

the samples analyzed, 61% contained illite, a mineral phase that decomposes at 900 °C. Illite was absent when diopside was present. This suggests that 77% of *figulina* from Pokrovnik was fired *below* 900 °C, and 33% fired at 900 °C. Samples from Krivače have the highest frequency of diopside at 93%, suggesting that *figulina* from Krivače was rich in dolomite and fired at temperatures of 900 °C. Smilčić and Danilo Bitinj are the only two sites with samples containing wollastonite, and they also have similar proportions of diopside and wollastonite. This suggests that a portion of the *figulina* samples were richer in calcite. Wollastonite and diopside form at the same temperature 900 °C, indicating that 63% of samples from Danilo Bitinj and 56% of samples from Smilčić were fired at temperatures of 900 °C. Based on the XRD analysis, Dalmatian potters fired *figulina* pottery at temperatures ranging from 800 to 900 °C (Trindade et al., 2009). These are temperatures that can be reached in an open pit firing (Rice, 1987).

4. Discussion

Significant skill and knowledge of raw material properties and firing was required to make *figulina* wares. The manufacture of *figulina* began with the careful selection of raw materials rich in calcium, iron, potash, and manganese (Spataro, 2002, 2009). Raw materials selected for *figulina* were crushed, sieved, and levigated, likely over several days or weeks in order to obtain a fine-grained clay body free of large mineral particulates. In some cases, the clay was tempered with small amounts of fine-grained calcite. The clay was then formed into vessels in shapes including jugs, hemispheric bowls, and plates. Some vessels were painted with red, brown, white, and black pigments. Once dry, the vessels were fired in an open-fire pit at temperatures up to 900 °C in an oxidizing environment.

For archaeologists, *figulina* is striking for three reasons. First, it is a relatively complex pottery technology that is a clear departure from earlier wares (Impressed Ware) in the same region. Secondly, it is distinctive from the majority of pottery production in the same period in terms of technology and decorative style – it appears to have been a labor intensive, time consuming activity for a pottery ware that constitutes only up to 4% of pottery produced and used during this period. And finally, it has clear parallels elsewhere in the Adriatic. This combination of unusualness coupled with ubiquity suggests that *figulina* must have had a functional, social, or ritual role to play that persisted for at least 500 years among farming populations in the Adriatic.

Based on our data, we suggest *figulina* was likely produced at a local level, by the village and largely for local consumption. There is no clear evidence for widespread trade of *figulina* pottery between sites, although some of our data suggest movement of at least some vessels between location of origin and site of recovery. PCA of the petrographic dataset from Krivače, Smilčić, Danilo Bitinj, and Pokrovnik clearly separates Pokrovnik and Danilo Bitinj into two distinct production locales based on community geologic signatures (Fig. 5). Despite their proximity to each other, there is little evidence for common production or widespread distribution of this pottery type.

Despite *figulina* not being widely traded regionally, Middle Neolithic potters throughout the Adriatic produced *figulina* pottery using the same methods and in a similar style. Why? One suggestion is that *figulina* was an expression of a social relationship linking coastal farming communities in Croatia and Italy (Teoh, 2011). This pottery may have represented a shared expression of group identity for communities within the Adriatic, linked by increased economic interaction in other goods (e.g., obsidian). In a study addressing the emergence of material social complexity in premodern non-state societies in India, Smith (1999) illustrated the value of an increase in material expressions as a means to reinforce social ties and kin-networks. An expansion of everyday goods provides a means for individuals in a group to proclaim their group identity (Smith, 1999). Although *figulina* was not exchanged between these regions, the production of this pottery form could have been used to signal association with wider regional identities. A trans-Adriatic and chronologically controlled analysis of *figulina* style and typology would be an interesting avenue to begin looking at this issue.

Alternatively, technological similarity may be due to desired functional characteristics or the role of pottery in daily Neolithic life. Advances in ceramic residue analyses, use wear studies, and pottery life histories including deposition and fragmentation could provide new insights (e.g., Chapman, 2000; Evershed, 2008; Evershed et al., 2008). A more specific site-based or region-based approach may well conclude that similarities in *figulina* on either side of the Adriatic are only on the surface, but that this pottery type may have fulfilled many different functions for Neolithic society.

5. Conclusions

The purpose, meaning and significance of *figulina* remain unclear, but it clearly represents an unusual kind of pottery. Our data

build upon previous petrographic and geochemical studies by focusing on larger samples of *figulina* from four Middle Neolithic villages in central Dalmatia. Mineralogical and chemical investigation of *figulina* pottery presented here indicates that *figulina* was variable and was likely produced locally within villages. *Figulina* is different than other locally produced wares during the Danilo Middle Neolithic, but its similarity to painted wares in Italy is striking. Future research is needed to investigate *figulina* typology in greater detail in order to identify if villages are differentiating themselves through external decoration. Residue analysis can also be applied to identify if *figulina* vessels had a specific function within the suite of pottery produced during this period. Finally, more detailed chronological work is needed to try to illuminate the timing, tempo, and significance of trans-Adriatic social and economic networks during the Middle Neolithic.

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